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(PLATE 4).

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FAILURES IN OATS DUE TO ROOT ROT CAUSED BY *GIBBERELLA ZEAE*

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Introduction.

Gibberella zeae (Schw.) Petch, is a well-known pathogen on many members of the Graminae, and it is often virulent on the small cereals. On the heads of wheat, barley, rye, and to a much lesser degree oats, the fungus causes the disease Ear Blight, with which the conidial stage *Fusarium graminearum* is usually associated. Under wet climatic conditions incrustations of perithecia frequently develop on the spikelets, and this constitutes the condition termed Cereal Scab (4). Grain in diseased heads is often undeveloped or shrunken, or if fully formed it shows various degrees of pink or reddish discoloration. Infected grain is toxic to farm animals, and in man, symptoms of nausea, vomiting, and intoxication, follow the consumption of bread made from diseased grain. In wet harvests when *Gibberella zeae* is prevalent on wheat ears much of the grain may be infected, and when this is sown it leads to thin brairds and to the third phase of disease known as Seedling Blight. Badly diseased kernels fail to germinate when sown. On the other hand, those slightly affected may sprout and give rise to poor seedlings, which either soon succumb to the fungus or which manage to struggle on as weak plants. Dead seedlings and infected plants provide suitable hosts on which the fungus can fructify. The fructifications which generally develop on such hosts are perithecia containing ascospores, but occasionally conidia may be produced, and both spore forms act as sources of infection to the new crop.

Whereas Seedling Blight of wheat has been extensively investigated and many papers published on the causal organism, throughout the literature on *Gibberella zeae* there are exceptionally few references to oat failures caused by attacks of this fungus on their roots.

The present paper deals mainly with severe attacks of *Gibberella zeae* on the root system of oat plants in Ireland in 1951, and on the general incidence of the fungus on this cereal.

The Occurrence of Oat Failures in 1951 due to *Gibberella Zeae*.

The first lot of diseased plants came to hand on the 27th June. They were forwarded for examination by Mr. Gerald O'Malley, Instructor in Agriculture, Co. Wexford. The accompanying letter stated that the plants were dying away as their root system was practically gone, and there was a dark discoloration at the base of the culms. In general the disease resembled Take All, *Ophiobolus graminis*. Three weeks later more similarly affected plants were received from another corres-

pondent in the south of Ireland. In this case the specimens were accompanied by a report which stated that the disease was prevalent over a six acre field, and the crop in one part of the field was affected to the extent of 90 per cent.

At this stage the co-operation of the Department of Agriculture was sought, and it accordingly issued a memorandum to all Instructors in Agriculture, asking that samples of any disease in grain crops should be forwarded for examination to the Plant Pathological Division, along with relevant data as to culture, rotation, etc. As a result, some 116 samples of cereal plants were submitted for examination during the season. These comprised 64 lots of wheat, 42 of oats, 9 of barley, and 1 of rye. An analysis of the various diseases which occurred on these specimens has been prepared and will be reported on elsewhere, but it may be stated here, that although many attacks of Take All, *Ophiobolus graminis*, were diagnosed, only four other cases of failures caused by *Gibberella zeae* were identified. These also occurred on oats, making a total of six cases of the disease on this cereal. Although this number is comparatively small, the attack in every instance caused serious loss. Furthermore, these six cases were all clear-cut attacks of *Gibberella zeae*, as in none of them were there any complications due to the presence of other organisms. The following are some details of these six fields :

Field No.	Diseased Plants Per Cent.	pH of soil	Date when sown	Previous Cropping	Manuring
1	Dying out in patches.	5.1	26 April	Grass.	2 cwt. compound fertilizer per acre.
2	60–90	5.2	14 May	Wheat, 1950, cereals for several years previously.	1½ cwt. superphosphate ; 5 stone muriate of potash ; 1¼ cwt. sulphate of ammonia per statute acre.
3	40–60	?	10 May	Third year under oats ; potatoes, 1948	3 cwt. compound fertilizer per acre.
4	40	5.0	10 May	Turnips, 1950, Oats, 1949 and 1948, Grass, 1947.	Phosphates and potash given, but no nitrogen.
5	40	5.0	20 May	Oats, 1950, 1949, 1948, 1947.	Superphosphate only applied.
6	30–40	5.0	6 May	Hay, 1950 and 1949, Oats, 1948, Roots, 1947.	Superphosphate only applied.

Victory, which is a white oat, was sown in field No. 1, but in the other five fields the variety was Black Tartary. No seed dressings were used.

Climatic conditions.—The months of August and September of 1950 had over 5.4 and 4.1 inches of rain, respectively, in Co. Dublin, and over the greater part of the country the precipitation was considerably higher for the same period. Although the rainfall for the remainder of that year was not above normal, in many districts no autumn cultivation of the land was possible owing to its saturated condition. There was comparatively little frost and snow in the winter of 1950–'51, and the ground never dried up to any degree, as the precipitation in January and February, 1951, was about average for these months, and March was wet with over 3 inches of rain. Some slight improvement took place in April, but on the whole temperatures were rather low, and the inclement conditions made the spring of 1951 exceptionally backward. Ploughing was held up everywhere, and hence the late dates given for sowing in the fields under review.

With reference to field No. 2. The area in this case was six acres, and the wheat crop in it was poor in 1950, a condition which was attributed to low fertility. A soil analysis confirmed this opinion, and an attempt was made to remedy the deficiencies by giving a complete fertilizer. As already stated sowing was late, and part only of this field was ploughed, the remainder of it being cultivated with the disc harrow. Whilst *Gibberella* attacks occurred all over this field, the disease reached its maximum intensity on the unploughed portion, 90 per cent. of the plants here being affected, and the crop a failure. The total yield of grain from this field was 70 cwt. Areas and total yields of grain of two other fields were, field No. 3, five statute acres, yield 80 cwt. grain ; and field No. 4, fourteen statute acres, yield of grain, 157 cwt. Taking 20 cwt. of oats as an average yield per statute acre, then the reduction in these three fields was approximately 41, 20, and 44 per cent., respectively.

Description of *Gibberella* attacks causing Failures in Oat Crops.

In the field the disease resembled severe attacks of *Ophiobolus graminis*, the cause of Take All. The affected plants occurred both indiscriminately throughout the crop and aggregated in patches of variable size. Dead and dying plants ranged in height from 6 to 20 inches (Fig. 1, Plate 4). The foliage was dry, without lesions, tough or papery to the feel, and of a uniform brown colour. When affected plants were pulled up they generally had a poor root system, as many of the roots had been destroyed by the fungus. Not infrequently such plants came away from the soil devoid of any roots whatever. In this respect the diseased plants differ from those attacked by Take All, where the root system so often presents a woolly or furred appearance. In *Gibberella* attacks, the black discoloration so obvious at the base of many plants, when examined with a pocket lens, was seen to be caused by aggregations of perithecia (Fig. 3, Plate 4). These were liberating ascospores before the end of June. Under very damp conditions the asci and ascospores exuded from the perithecia as white masses (Fig. 4, Plate 4). When dead plants which had no visible fructifications were placed with their base on wet cotton wool in a vessel, they either

developed a dirty white or pinkish growth of hyphae bearing conidia, *Fusarium graminearum* (Fig. 2, Plate 4), or they gave rise to perithecia. In all cases, however, fructifications only developed on a very restricted region of the plant within 2 or 3 inches of the soil-level mark. This phase of disease therefore is essentially one of the roots, crown, and base of the stem. When the last mentioned is invaded by the pathogen the fungus does not grow up the plant to any extent, but the invasion of the stem cuts off all supplies to the parts above, which soon die and dry up.

Sometimes in the field a complete collar of perithecia occurred around the stem. These fructifications were also found within the sheathing leaf at the base of the plant, and occasionally on roots contiguous to the stem base. The perithecia were dull black in colour and showed little of the inky-blue appearance which was previously seen on those occurring on wheat heads. In all other respects they conformed to the type, and measurements of asci, ascospores and conidia were well within the range of those recorded for *Gibberella zeae*.

The incidence of *Gibberella Zeae* on Oats.

Although this fungus has been found repeatedly on oat spikelets causing blighting and scabbing of the grain, the conclusion reached by the majority of workers who have studied *Gibberella zeae* is that oats are only slightly susceptible to its attack. On the other hand, Rainio (8), reports oats as being badly infected in Finland ; and in America Chih Tu (2) found certain strains of the fungus to attack oats more severely than wheat. As regards these islands, Dennis (3) in 1944, stated that *Gibberella zeae* had been prevalent in recent years on ripening oats in Scotland ; and Moore (6) records oats as being the chief cereal affected by the fungus in Wales in 1942, but also mentions other cases of it on oats elsewhere in England. During the epidemic of the disease on wheat in Ireland in 1942 (4), only two cases of infected oats came to hand, but it was surmised then that the disease on this cereal may have been more prevalent than this number indicated. However, an examination of numerous diseased cereals during the next two years showed that *Gibberella zeae* was much more common on wheat than on oats in this country. The figures for the two years are, 1943, *Gibberella zeae* on wheat, 62 samples, on oats, nil ; and in 1944, 63 samples of affected wheat were found against 8 of oats (5).

The foregoing remarks in this section all refer to attacks of the fungus on cereal heads.

When oat spikelets are attacked by the fungus, the latter seldom spreads to the central axis, therefore there is no cutting off of food supplies from other spikelets, and the disease is not nearly so destructive as it is in the case of wheat ears. Furthermore, owing to the open nature of the oat panicle the relative number of affected spikelets is generally small, hence, the percentage of infected grain is much lower than what occurs in wheat. Evidence in support of this is forthcoming from data made available to the writer through the courtesy of Dr. H. A. Lafferty, Head of the Seed Testing Station, Department of Agriculture, Dublin.

As was pointed out in a previous paper (4), after the harvest of 1938, attention began to be paid in the Seed Testing Station to a red fungus which was occurring on cereal samples undergoing germination tests. The exact identification of this fungus was not ascertained, but it was recognised as a *Fusarium* spp., and it was labelled " Red Disease". The following data shows the percentage of this " Red Disease " occurring on wheat and white oats in the Seed Testing Station over the last nine years. Black oats are omitted, as the number of samples of these tested has been so small the figures are insignificant.

	Wheat.		White Oats.	
Harvest Year	No. of Samples tested.	% of Samples showing " Red Disease".	No. of Samples tested.	% of Samples showing " Red Disease".
1942	5,164	25	1,234	6
1943	5,032	21	1,650	2
1944	5,540	22	1,306	3
1945	5,002	15	1,242	1
1946	5,395	29	1,645	6
1947	5,084	10	1,552	3
1948	3,496	9	991	1
1949	3,197	7	1,139	1
1950	3,230	20	1,373	4

All this " Red Disease " is not necessarily caused by *Gibberella zeae*, as several other fungi, and especially species of *Fusarium*, produce similar discoloration in cereal grains ; but *Gibberella zeae* is of frequent occurrence, and it is probably the most predominant organism involved. In any case, it is evident from the above figures that infected wheat is much more prevalent than infected oats.

Discussion.

As regards the grain and the susceptibility of oat varieties to *Gibberella zeae*, Rainio (8), found that some correlation appears to exist between the colour of the oat husks and reaction to the fungus, the white varieties being more susceptible than black or brown ones. Moore (6), also states that during the severe attacks of Ear Blight on oats in mid-Wales in 1942, black varieties remained relatively free from attack. Five of the six recorded cases of oat failures in Ireland in 1951 occurred on black oats ; here, of course, the attack was on the root system of the plants and not on the panicles.

In the case of Seedling Blight of wheat due to *Gibberella zeae*, the disease is known to arise both from infected grain and from infected soil, and Rainio (8), found the same sources of infection operative in the case of oats. Dennis (3), has reported that some species of *Fusarium* are apparently responsible for low brairds of oats sown under poor soil conditions in Scotland, but, as a result of experiments con-

ducted both in the laboratory and in the field, this worker concluded that *Gibberella zeae* has no effect whatever on seedling growth or emergence in oats. Bennett (1), who studied this fungus in England, isolated it from the base of several cereal plants including oats, and found it to be widespread. He states, however, that although *Gibberella zeae* causes Seedling Blight and Foot Rot it is much less virulent in this respect than *Fusarium culmorum* and *F. avenaceum*. In a recent survey of root rots in cereal crops in California, Oswald (7), reports that *Gibberella*-producing clones predominate, although perithecia seldom occurred in the field. In second place amongst fungi of primary importance in these rots Oswald (7), places *Fusarium roseum f. cerealis* (syn. *F. graminearum*, the conidial stage of *Gibberella zeae*). This fungus was one of the commonest isolated from oat roots. Nevertheless, the same worker writes, " In fields where severe damage has been previously experienced with wheat and barley, oats have been unaffected by the *Gibberella*-producing clones of this *Fusarium*. In the greenhouse, with heavy artificial inoculation, oats may become infected, but even there seem to have a high tolerance to the fungus." And he goes on to say, " a field rotation with oats generally constitutes a practical control measure ".

In view of the evidence available regarding the Irish failures, it is unlikely that the infection came from the seed ; and generally speaking, oats are not nearly so susceptible to root rotting fungi as wheat and barley. Where infection comes from the stubble of a previous crop, either cereals or grass, late ploughing in spring is a contributory factor to disease, as the old stubble has no time to decay. This may well have been the predisposing factor to attack in the majority of cases recorded, as ploughing in every instance just preceded sowing owing to the backwardness of the spring and the inclement weather. Evidence in support of the old stubble being the source of infection is furnished by the part of field No. 2 which was not ploughed but only cultivated by disc harrowing, here the disease reached its maximum intensity. The same argument as to source of infection cannot be applied to field No. 4 where turnips were grown the previous year, but no information is available about this particular field as to its freedom from volunteer oat plants or weeds in 1950.

Continual cropping with cereals is detrimental to land, and tends not only to impoverish the soil but also to the increase of pathogenic soil organisms. The correction of nutrient deficiencies no doubt alleviates the symptoms of attack in such cases, but it does not control soil diseases to any extent. Some of the cases quoted are good examples of this point.

At the present time there are certain advocates who teach that ploughing is unnecessary in the case of cereal growing. According to these authorities all that is required is to simply cultivate the soil surface. Scratching of the soil surface is not farming, and in every sense it is bad husbandry, and is especially fatal where cereal root rotting organisms are concerned.

Finally, it will have been noted that five of the six attacks occurred on very acid soils, and the sixth was also acid as judged by its weed flora, the following plants

predominating, spurrey, *Spergula arvensis*, corn marigold, *Chrysanthemum segetum*, and sheeps sorrell, *Rumex acetosella*. The significance of soil acidity with susceptibility to *Gibberella zeae* is not clear at present, but this point might be well worthy of further investigation as well as that of specialized strains of the fungus.

Acknowledgements are tendered to the Department of Agriculture for facilitating the writer in his inquiries, and to all Instructors in Agriculture who co-operated by sending in diseased specimens.

Summary.

An account is given of some failures in oat crops in Ireland in 1951 due to root rot caused by *Gibberella zeae*.

The general appearance of the disease in the field simulated severe attacks of Take All, *Ophiobolus graminis* ; the dead and dying plants ranging in height from six to twenty inches, with many culms blackened at their base.

This dark discoloration was due to a prolific development of perithecia of *Gibberella zeae*. No other organism was involved, and ascospores were being liberated before the end of June.

Five of the six fields where the disease occurred were sown with black oats, and the percentage of affected plants ranged from 30 to 90. The maximum intensity of the disease occurred on part of one field which was not ploughed, the ground being cultivated with a disc harrow.

Total yields at harvest time from three of the affected fields showed reduced yields of approximately 41, 20 and 44 per cent ; taking 20 cwt. of oats as an average yield per statute acre.

The soil pH in five of the fields only varied from 5.0 to 5.2, and the weed flora in the sixth field also indicated an acid soil.

Rotation of crops is recorded, and the general incidence of *Gibberella zeae* on oats is discussed.

Explanation of Plate 4.

Fig. 1. General appearance of stunted dead and dying oat plants, the result of virulent attacks of *Gibberella zeae* at and below soil level. More than half these plants have perithecia of the fungus present just above soil level. Note the poor root system of the plants.

Fig. 2. Three oat plants from group in Fig. 1 which were devoid of any fructification, showing development of mycelium bearing conidia of *Fusarium graminearum* (*Gibberella zeae*) after being placed with their stem bases resting on moist cotton wool in a vessel 72 hours.
Upper portions of host plants free from the fungus.

FIG. 3. Base of oat stem showing prolific development of perithecia of *Gibberella zeae*. Typical of many plants in Fig. 1. (× 3).

FIG. 4. Base of oat plant showing perithecia of *Gibberella zeae* exuding white masses of asci and ascospores under damp conditions. (× 15).

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FIGURE 1.

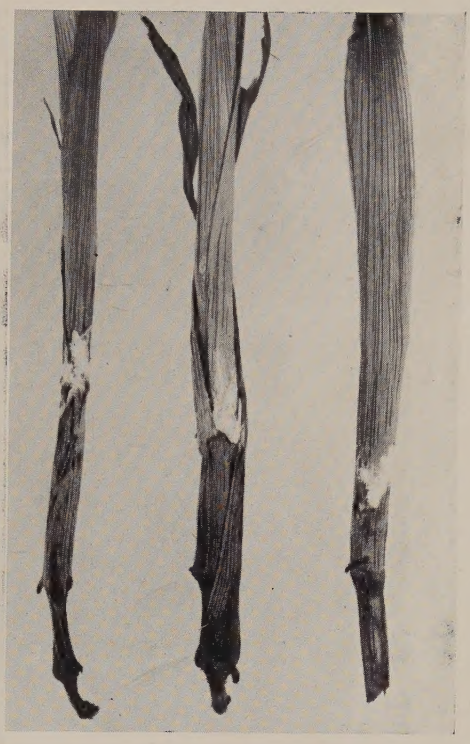

FIGURE 2.

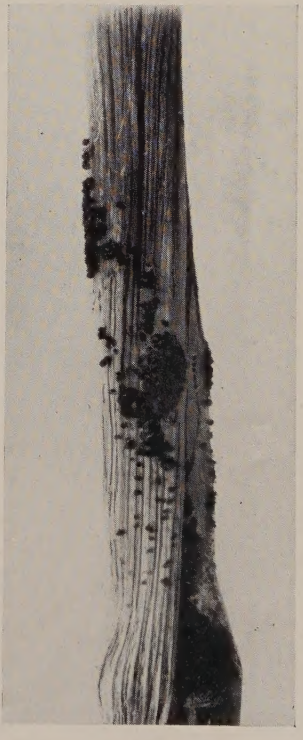

FIGURE 3.

FIGURE 4.